

# Lunar Reconnaissance Orbiter: (CRaTER)

## Audience

Grades 6-8

## Time Recommended

45-60 minutes

## AAAS STANDARDS

- 1B/1: Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
- 3A/M2: Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

## NSES STANDARDS

Content Standard A (5-8): Abilities necessary to do scientific inquiry:

- c. Use appropriate tools to gather, analyze and interpret data.
- e. Think critically and logically to make relationships between evidence and explanations

Content Standard E (5-8): Science and Technology:

- e. Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

## MATERIALS

- Copies of the pictures (located in procedure section)
- Very clear jar with a metal lid
- Denatured alcohol
- Black construction paper
- Sponge
- Pen or pencil
- Flashlight
- Dry ice, which you may be able to find this at an ice cream shop or a grocery store
- (Optional) a small radioactive source that emits energetic helium nuclei (alpha particles), e.g. a lead-210 or polonium-210 needle source

# CRaTER: How to Detect Cosmic Rays

## Learning Objectives:

- The students will be able to explain two examples of a cosmic ray detector.
- Students will learn how cosmic rays can affect us here on Earth.

## Preparation:

See activity procedure for details.

## Background Information:

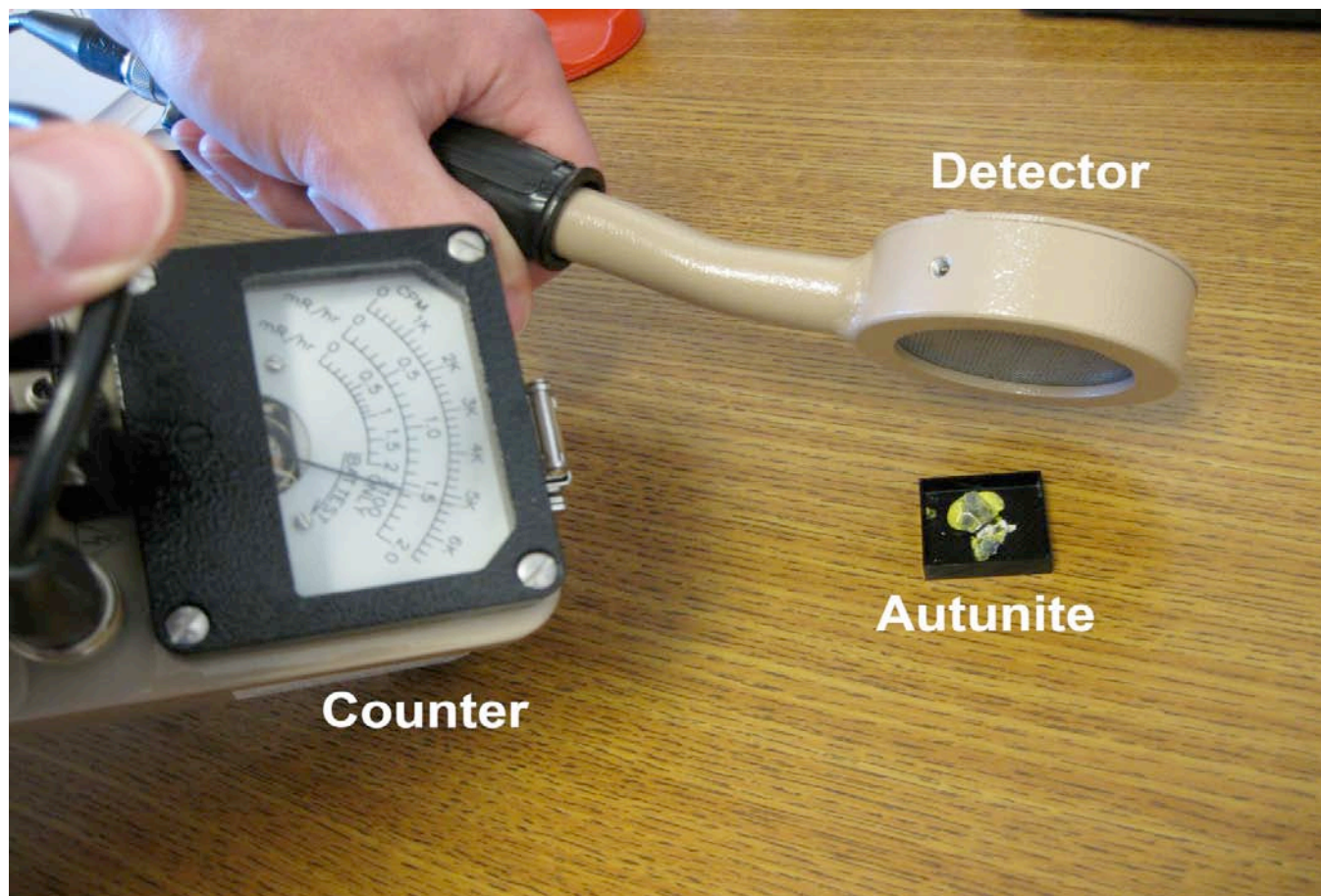
To understand the effects of cosmic rays, we need to be able to detect them. A variety of methods exist. One detector you may have seen or heard, especially in movies, is a Geiger counter (see Figure 1). This instrument can detect various forms of particle radiation and electromagnetic radiation, as discussed in the previous lesson. The sources of particle radiation can be radioactive materials, like uranium, or cosmic rays. (See picture on next page)

The Geiger counter has a small chamber of inert gas. When a photon or subatomic particle passes through the chamber, it can collide with some of the atoms in the gas, stripping them of their electrons. This creates a small current in the gas like the current in electroscopes. The Geiger counter detects the current. If the counter has a speaker, you will hear clicking sounds when the instrument detects radiation.

The Lunar Reconnaissance Orbiter (LRO) carries a detector called the Cosmic Ray Telescope for the Effects of Radiation, or CRaTER. Instead of using gas like the Geiger counter, CRaTER uses a solid to detect cosmic rays. It contains six disks made from silicon; they are called solid-state detectors. Such detectors are much more compact than one which uses a gas. A cosmic ray that passes through this detector will create a small current CRaTER's computer measures.

Although the cloud chamber seems like a simple device, it was instrumental in discovering new subatomic particles. When cosmic rays collide with atoms in Earth's atmosphere, they create secondary subatomic particles. In 1932, a physicist named Carl Anderson discovered the positron (an antimatter electron, or "electron" with a positive charge) in his cloud chamber. He received the Nobel Prize for this. Anderson next discovered in 1936 a negatively charged particle called the muon. Both particles were the result of using a cloud chamber.

If you could take a cosmic ray detector into outer space, you would see many, many more cosmic rays than here on the ground. That is because the atmosphere shields us from all cosmic rays except for the most energetic. Outside the atmosphere, however, there is no protection against these particles.



**Figure 1.** A Geiger counter. The detector in the left hand is connected by a wire to the counter on the right. The radioactive source in the small black box on the right is the mineral autunite, which contains radioactive uranium. If you were to move the detector far away from the autunite, the counter would be very close to zero (but not quite, because of cosmic rays). Don't worry; autunite, although radioactive, is not dangerous.

## Procedure:

### PRE-ACTIVITY QUESTIONS:

- Do you think any cosmic rays are going through your classroom right now? How can you tell?

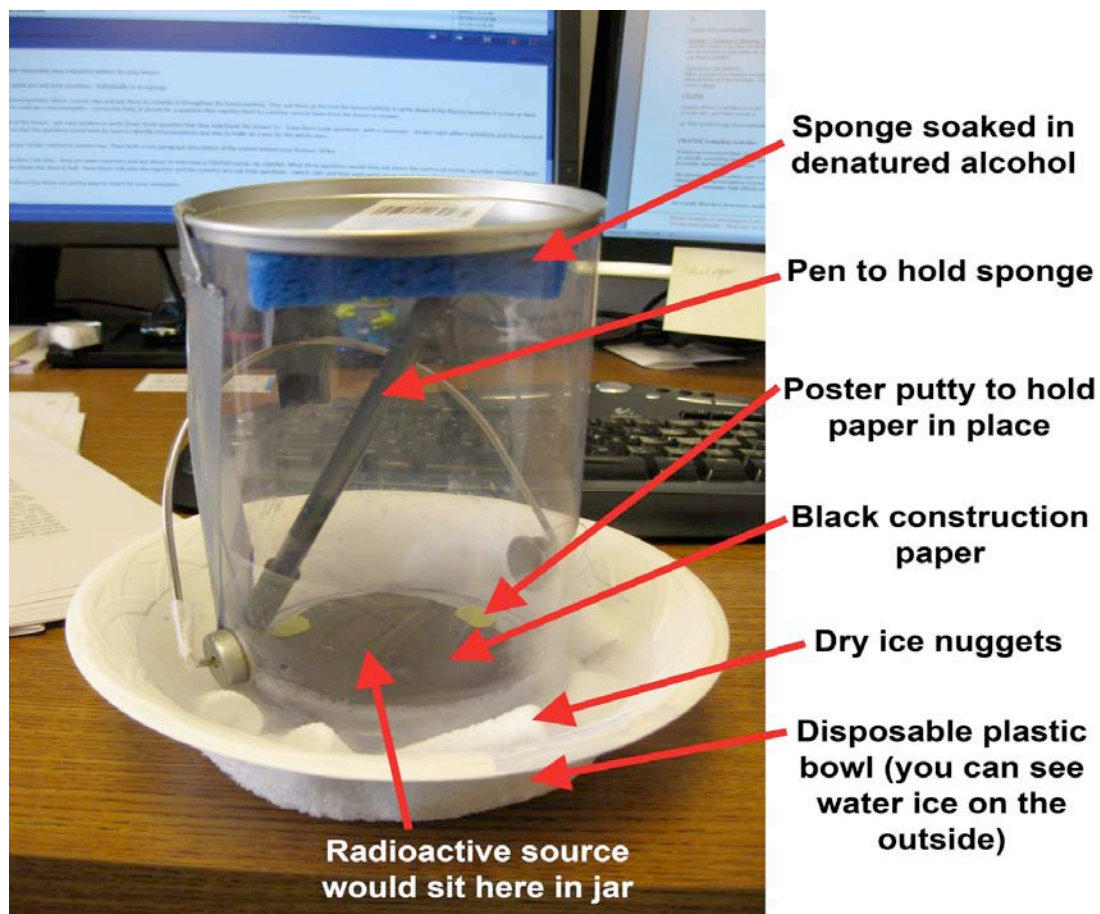
### MATERIALS:

- Very clear jar with a metal lid (using a transparent paint can from a craft store is helpful: about 6 inches tall and 4 inches in diameter)
- Denatured alcohol
- Black construction paper
- Sponge
- Pen or pencil (for propping the sponge)
- Flashlight (a small one with white LEDs works well)
- Dry ice, which you may be able to find this at an ice cream shop or grocery store (use gloves, such as oven mitts, when handling dry ice!)
- Optional: a small radioactive source that emits energetic helium nuclei (alpha particles), e.g. a lead-210 or polonium-210 needle source

### SETUP:

1. Before doing this experiment, you may want to watch a guided version of this activity done by Jefferson Lab ( [http://education.jlab.org/frost/cloud\\_chamber.html](http://education.jlab.org/frost/cloud_chamber.html) ). If you don't use a radioactive source, you won't see as many trails. The video, however, will give you an idea of what to look for.
2. Lay the black construction paper on the inside of the lid.
3. Thoroughly soak the sponge in the alcohol, and squeeze out just a bit of the excess.
4. Use the pen or pencil to jam (no looseness!) the sponge onto the bottom of the jar. This is important because you will be using the jar upside down.
5. Place the lid on. Make sure it seals completely. (If you use a radioactive source, it should sit on the lid.)
6. Turn the jar upside down. Make sure the pen or pencil is firmly in place; it will keep the sponge from falling. Also, make sure the construction paper stays on the lid.
7. Let the jar sit for between 5 and 10 minutes. This gives the alcohol vapor enough time to saturate the air inside the jar.
8. Place the jar, still upside down, on top of the dry ice. See **Figure 2** for examples of the following directions. Wait for no more than five minutes.
9. Darken the room.
10. Shine the flashlight perpendicularly to your eyes and near the jar's lid and watch carefully. You will see the fine mist of alcohol rain falling. As the air in the jar cools, the vaporized alcohol condenses and rains to the bottom. The dry ice cools the very lowest part of the jar (closest to the lid) so much the air becomes supersaturated with alcohol. Supersaturation means that the air contains more alcohol vapor than possible under normal circumstances. With patience and practice, you will see small contrails form near the lid every few seconds. A contrail looks like a miniature version of a jet contrail in the sky: a long, thin streak of cloud. Most people don't see the contrails until they know what they're looking for. It helps to focus on one spot on the lid. You may have to vary the angle between the light and your eyes to find the best angle.

## EXAMPLE:



**Figure 2.** It's hard to imagine that this simple setup can detect such energetic and minute particles! (I put duct tape along a seam in the jar's side to improve air-tightness. This is optional.)

## FACILITATION QUESTIONS/ ANSWERS:

*What is happening?* Alcohol vapor fills the jar. The lid sits on the dry ice. Therefore, the dry ice cools the air near the lid, allowing the air to become supersaturated with alcohol. The particles created by cosmic rays collide with and ionize the particles in the air. The newly formed ions are the seed particles onto which the alcohol can condense. Although subatomic particles are too small to see, the cloud chamber makes their effects visible.

The original cosmic rays don't cause the contrails you see. Primary cosmic rays do not make it all the way down to Earth's surface. They collide with molecules in the atmosphere. These collisions create secondary cosmic rays, which are other subatomic particles with less energy. These secondary cosmic rays can collide with other molecules and create even more secondaries, producing a cosmic ray air shower. Showers happen all the time, but they are invisible to your eyes. **Figure 3** (on next page) shows a computer simulation of an air shower. You can find air shower movies at:

<http://astro.uchicago.edu/cosmos/projects/aires>.

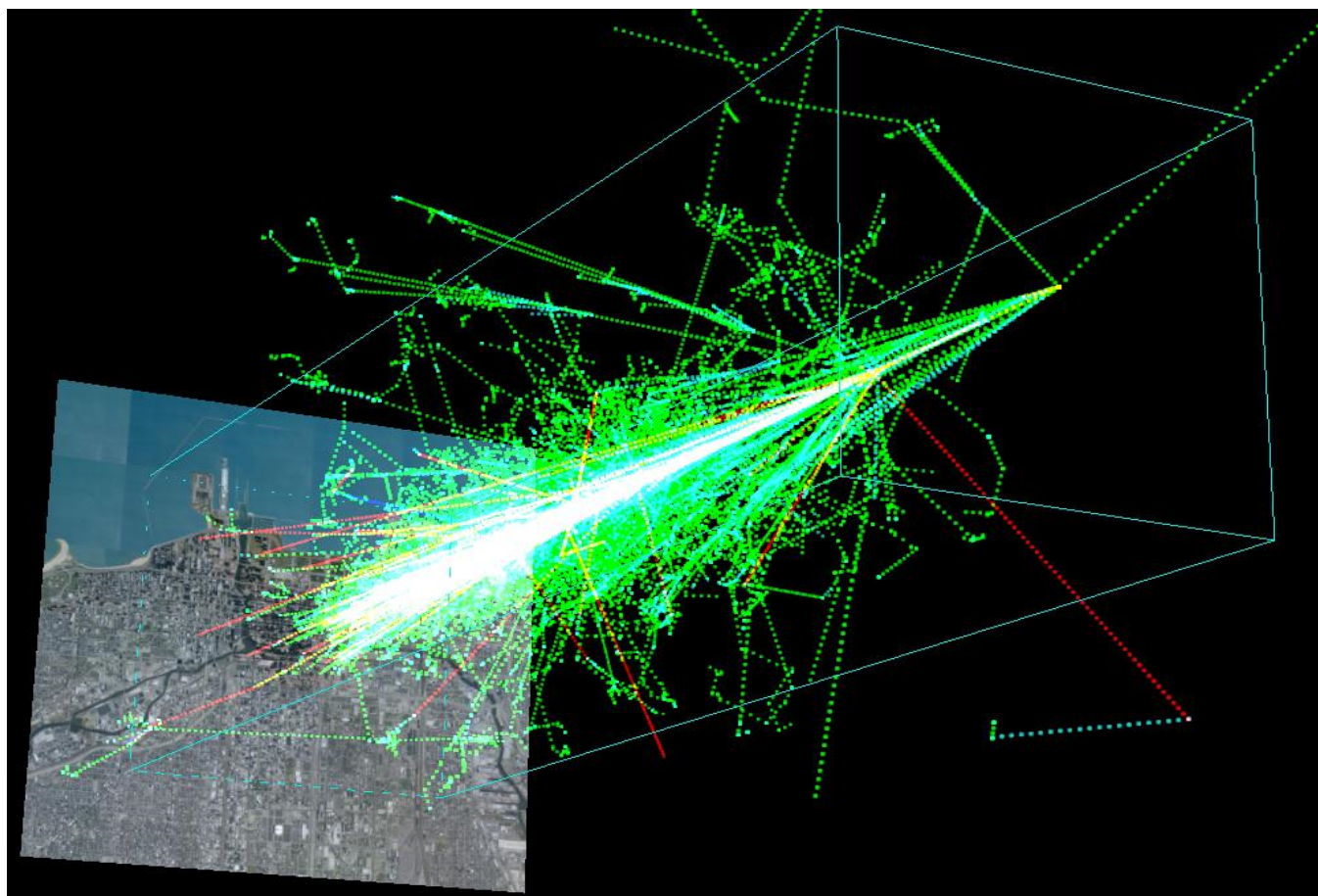
Think about how far the cosmic rays might have traveled before hitting Earth's atmosphere and creating the tiny contrails you see. Some of them might have come from clear across the Milky Way galaxy! Some of their secondary cosmic rays (a little less than 100 each second) are even getting into your body or passing right through it. Thankfully, their effect is minimal.



## Optional Activity:

If dry ice is unavailable, you can construct an alternative cosmic ray detector using a digital camera able to keep its shutter open more than a minute. Cover the lens so no light penetrates the camera. Use the highest ISO (International Standards Organization) setting available; this makes the film as sensitive as possible to light. Then, set the exposure time for about 5 minutes. You should see small streaks in the resulting image. These are the tracks of secondary cosmic rays. Digital cameras have noise-reducing programming built into their computers, so some cosmic ray tracks may be erased. For further details, see Kendra Sibbersen's article, "Catching Cosmic Rays with a DSLR," in *Astronomy Education Review*, vol. 9, issue 1, 5 August 2010.

This cosmic ray "noise" is a big problem with highly sensitive digital cameras used for astronomy. Astronomers need to detect faint objects, so they must keep the shutter open for many minutes. The long exposure time, however, means that there will be many cosmic ray tracks in the image. The problem is worse for the Hubble Space Telescope because it is outside the atmosphere where there are more cosmic rays. Astronomers must take multiple images and then carefully subtract the cosmic ray tracks. See <http://blogs.zooniverse.org/galaxyzoo/2010/04/12/how-to-handle-hubble-images> for more information and images. (This website is part of Zooniverse, a scientific project in which the public can help classify galaxies.)



**Figure 3.** This figure from a computer model shows an extremely energetic proton (coming in from the upper right) creating an air shower. The path of the original proton is labeled. (Image courtesy Maximo Ave, Dinoj Surendran, Tokonatsu Yamamoto, Randy Landsberf, Mark SubbaRao, and Sergio Sciutto and his ARIES package.)

### Note: Misconception

Some people think space is completely empty, except for stars and planets. If you could use your cloud chamber in space, you would actually find that the space contains many particles (not to mention electromagnetic fields). It is important to remember, however, the "vacuum" of space is still more vacuous than anything achievable in a laboratory. The density is only a few particles per cubic centimeter!

## Assessment:

**Time:** 10-15 minutes

**Materials:** Pencil and paper

**Objective:** The student will use what they have learned to create concise descriptions of cosmic rays.

Create a bumper sticker about cosmic rays. Then, write one paragraph describing the science behind your bumper sticker.

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## SUPPLEMENTAL IMAGES/ MATERIALS/ RESOURCES:

### Resources:

#### Information about CRaTER and LRO

LRO site:

[www.lunar.gsfc.nasa.gov](http://www.lunar.gsfc.nasa.gov)

CRaTER's website:

[www.crater.unh.edu](http://www.crater.unh.edu)

A video in which the man responsible for CRaTER describes cosmic rays and the instrument:

[www.nasa.gov/multimedia/nasatv/on\\_demand\\_video.html?param=http://anon.nasa-global.edgesuite.net/anon.nasa-global/ccvideos/GSFC\\_20090416\\_LRO\\_CRaTERvideo.aspx](http://www.nasa.gov/multimedia/nasatv/on_demand_video.html?param=http://anon.nasa-global.edgesuite.net/anon.nasa-global/ccvideos/GSFC_20090416_LRO_CRaTERvideo.aspx)

#### General information about cosmic rays

*A Thin Cosmic Rain: Particles from Outer Space* (previously published as *Cosmic Rays*), Cambridge, MA: Harvard, 2000.

*Cosmicopia: An Abundance of Cosmic Rays* (a NASA Goddard website about cosmic rays):

[helios.gsfc.nasa.gov/cosmic.html](http://helios.gsfc.nasa.gov/cosmic.html)

Cosmic ray comic book:

[www.scostep.ucar.edu/comics/books](http://www.scostep.ucar.edu/comics/books), then click on the file labeled cosmicrays\_e.pdf.

Air shower movies generated from the ARIES (Air shower Extended Simulations):

<http://astro.uchicago.edu/cosmus/projects/aires>

#### Space Radiation

Space Radiation Analysis Group at Johnson Space Center:

<http://srag-nt.jsc.nasa.gov>

Eugene N. Parker, "Shielding Space Travelers," *Scientific American*, March 2006.

M.G. Lord, "Are We Trapped On Earth?" *Discover*, June 2006.

Cosmic rays and cataracts:

[http://science.nasa.gov/science-news/science-at-nasa/2004/22oct\\_cataracts](http://science.nasa.gov/science-news/science-at-nasa/2004/22oct_cataracts)

A NASA 6-12 educators guide to radiation math, with worksheets for students:

[www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Radiation\\_Math.htm](http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Radiation_Math.htm)

## Glossary:

**ALFMED:** Apollo Light Flash Moving Emulsion Detector, designed to detect whether cosmic rays create small flashes in astronauts' vision

**ALTEA:** Anomalous Long Term Effects in Astronauts' Central Nervous System; a device onboard the ISS to determine how cosmic rays affect the human brain

**Atom:** the smallest particle that still has the chemical qualities of an element; composed of a nucleus and electrons

**Cosmic ray:** an ion or electron in space that travels at a speed similar to that of light

**CRaTER:** Cosmic Ray Telescope for the Effects of Radiation; an instrument on the Lunar Reconnaissance Orbiter designed to study particle radiation near the moon

**Electroencephalograph:** an instrument that records the brain's electrical activity

**Electromagnetic radiation:** energy emitted in the form of electric and magnetic waves

**Electron:** a negatively charge subatomic particle; one of three particles to comprise atoms

**Electroscope:** a scientific tool used to store electric charge

**Emulsion:** a gel-like substance used to detect electromagnetic or particle radiation

**ISS:** International Space Station

**LRO:** Lunar Reconnaissance Orbiter; a spacecraft designed to study the moon's resources and radiation environment

**NASA:** National Aeronautics and Space Administration

**Nucleus:** the core of an atom, consisting of at least a proton (in hydrogen), or protons and neutrons

**Particle radiation:** energy emitted in the form of subatomic particles

**Phosphor:** a material that, when stimulated, emits electromagnetic radiation

**Proton:** a positively charged subatomic particle; one of two particles to comprise atomic nuclei

**TEP:** tissue-equivalent plastic, which has radiation-absorbing properties similar to human tissue

**Radioactivity:** the condition of a substance to emit ionizing particle or electromagnetic radiation